concentration of said second predetermined substance in said dialysis fluid.

25. The apparatus of claim 23 wherein said second predetermined substance comprises a substance selected from the group consisting of sodium ions, a conductivity altering substance and urea.

26. The apparatus of claim 25 wherein said second predetermined substance comprises urea.

REMARKS

The above-noted cancellation of claims 1-12, and substitution of new claims 13-26, as well as the substitution of a revised Abstract and Specification, are respectfully submitted prior to initiation of the prosecution of this application in the U.S. Patent and Trademark Office.

The above-noted amendments to the claims are respectfully submitted in order to more clearly and appropriately claim the subject matter which applicant considers to constitute his inventive contribution. No new matter is included in these amendments. In addition, a revised Abstract and Specification are submitted in order to clarify and correct the Specification and to conform it to all of the requirements of U.S. practice. No new matter is included in these amendments, and a copy of the marked-up Specification is respectfully submitted herewith in order to confirm same.

In view of the above, it is respectfully requested that these amendments now be entered, and that prosecution on the merits of this application now be initiated. If, however, for any reason the Examiner does not believe such action can be taken, it is respectfully requested that he telephone applicant's attorney at (908) 654-5000 in order to overcome any objections which he may have.

If there are any additional charges in connection with this requested amendment, the Examiner is authorized to charge applicant's Deposit Account No. 12-1095 therefor.

Respectfully submitted,

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TITLE: METHOD AND DEVICE FOR CALCULATING DIALYSIS EFFICIENCY

~~AREA~~ Field OF THE INVENTION

The present invention relates to a method and ~~device~~ apparatus for calculating dialysis efficiency. More specifically, the present invention relates to a non-invasive method and ~~device~~ apparatus for obtaining an initial concentration of urea and/or other solutes present in blood for further calculation of dialysis parameters.

The present invention is intended to be used during dialysis treatment, such as hemodialysis, hemodiafiltration or hemofiltration. It can also be used for peritoneal dialysis treatments. However, the present invention is not limited to the above-mentioned treatment modes, but can also be used for other medical or non-medical purposes.

~~PRIOR ART~~ BACKGROUND OF THE INVENTION

A method and ~~device~~ apparatus for calculating dialysis efficiency is disclosed in Swedish Patent Application No. 9702074-7, filed on 1997-06-02, by ~~Applicant~~ Gambro AB. In ~~said~~ the Swedish Patent Application, a whole body relative efficiency is calculated. The calculation uses a removed urea concentration curve obtained by a urea monitor during dialysis treatment. The urea monitor measures the concentration of urea in the effluent fluid from the dialyser, normally emitted to the drain. The result obtained by the urea monitor is a value of the removed mass of urea m_{rem} as well as the removed urea concentration curve, from which can be calculated the total accumulated urea mass m_0 in the body, whole body dialysis dose Kt/V, solute removal index SRI, etc. It is necessary

~~It is,~~ According to ~~said~~ the Swedish Patent Application, ~~required~~ to obtain a value of the initial concentration of urea in blood in order to be able to fully characterise the dialysis treatment.

Another approach, also described, is to obtain a value of the total body water volume V of the patient, whereupon the urea concentration in the blood of the patient may be calculated.

A number of different approaches to obtain said initial concentration of urea are given in said Patent Application, like blood sample or equilibrated dialysis solution before the start of the treatment. These methods are more or less problematic and there is a desire to eliminate manual intervention. Moreover, blood samples need to be taken before the initiation of dialysis treatment. As soon as the treatment starts, the initial blood concentration of urea is diluted due to cardio-pulmonary recirculation and access recirculation. Thus, care must be exercised to obtain the initial urea concentration before it is compromised.

SUMMARY OF INVENTION

The object of the present invention is to provide a method and a device for obtaining the initial urea concentration in blood before the dialysis treatment, to be used in the invention according to Swedish Patent Application No. 9702074-7 for calculating essential dialysis related parameters of a patient.

SUMMARY OF THE INVENTION

Specifically, it is possible to use the total body urea mass m_0, obtained according to said Swedish Patent Application No. 9702074-7, and the initial urea concentration c_0 in blood obtained according to the present invention for calculating the distribution volume V of urea in the body. This parameter V is expected to be constant from the end of one treatment to the end of the next, and could be used as an alternative to dry body weight as a parameter for determining the required ultrafiltration during a dialysis treatment. Moreover, the distribution volume V may be a long term marker for the general status of the patient.

A method of determining the dialysance of a dialyser used during dialysis treatment is disclosed in EP 658 352 filed by Hospal AG. According to this method, a disturbance is generated in the fresh dialysis solution before the dialyser and the resultant effect in the dialysate after the dialyser is

measured. Normally, the disturbance is induced in the conductivity of the dialysis solution. [The] This method [gives] provides the effective ionic dialysance for the dialyser and the effective plasma conductivity.

In clinical studies this ionic dialysance for a dialyser measured according to [EP] European Application No. 658,352 has been shown to agree well with the effective plasma water clearance of that dialyser for urea (K_e), i.e. plasma water clearance corrected for recirculation, pulmonary recirculation as well as access recirculation.

The definition of clearance implies that the urea mass removal rate equals the product of the effective plasma water clearance (K_e) and plasma water concentration (c_{pw}) of urea in the systemic blood returning from the body. The difference between dialyser clearance and effective dialyser clearance is that for dialyser clearance the denominator should be plasma water concentration in the blood entering the dialyser while for effective dialyser clearance the denominator should be plasma water concentration in the systemic blood returning from the body. Due to recirculation this concentration in the blood entering the dialyser differs from the concentration in the systemic blood returning from the body.

The urea mass removal rate is measured by the urea monitor as the product of dialysate flow rate (Q_d) and the urea concentration in the spent dialysate (c_d). We can therefore equate the two expressions for urea mass removal rate from plasma water and into the spent dialysate

$$K_e \times c_{pw} = Q_d \times c_d$$

In this equation, K_e may be obtained by the method of [EP] European Application No. 658,352 or a similar method, while Q_d and c_d are obtained by the urea monitor. Thus, c_{pw} can be calculated.

There is, however, an additional effect that has to be taken into account. Due to internal resistance in the body to urea transport, a urea gradient starts to develop within the body from the start of a dialysis treatment. This means that the urea concentrations in different parts of the body are

gradually differing more and more, and the urea concentration in the blood returning from the body, which is used in the calculations above, is no longer representative of the mean urea concentration in the body. It is therefore only before or ~~at~~ during the initiation of a treatment, while urea is equally distributed in the body, that the calculation above can be used to find the mean urea concentration in the body.

The urea monitor is programmed to find the starting value for dialysate urea c_{d0} by interpolating backwards along the concentration curve using measurements from 20 to 5 minutes after the treatment start time, which is defined as the time when the measured dialysate urea concentration c_d is steadily above a predetermined low concentration value. Due to time constants in the monitor this starting value will not catch the initial decrease in urea due to the development of recirculation, so this initial dialysate urea concentration c_{d0} will be representative of conditions with recirculation already developed. Using this starting value of c_d in the formula above, together with a measurement of effective clearance (K_e) performed, ~~by~~ for example, by the method described in European Patent Application No. ~~EP~~ 658,352, will produce the initial plasma water concentration c_{pw0} of urea in the blood returning from the body. At the start, before any gradients have developed in the body, this will also be the mean plasma water concentration in the body. The measurement of effective clearance K_e should preferably be performed as soon as possible after the initial 20 minutes (for the interpolation of initial dialysate urea) to avoid unintentional changes in clearance, and all factors affecting clearance such as blood and dialysate flows should be kept constant during this period.

→ [Insert A] ← attached

BRIEF DESCRIPTION OF THE DRAWINGS

→ [Insert 1] ← attached

Fig. 1 is a schematic view of a dialysis machine intended for hemodialysis including a urea monitor, and ~~where~~ in connection with which the present invention can be used.

Fig. 2 is a schematic view similar to Fig. 1, but with the urea monitor integrated in the dialysis machine.

Fig. 3 is a schematic view similar to Fig. 1 of a dialysis machine adapted for predilution hemofiltration.

Fig. 4 is a schematic view similar to Fig. 2 of a dialysis machine adapted for postdilution hemofiltration.; and

Fig. 5 is a graphical representation of ~~diagram over~~ concentration values obtained from the urea monitor in the dialysis machine according to anyone of Figs. 1 - 4.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Referring to the figures, in which like reference numerals refer to like elements throughout, Fig. 1 is a schematic diagram of a dialysis machine in which the invention according to Swedish Patent Application No. 9702074-7 and the present invention can be practised. The dialysis machine provides means for replacing the renal function of a mammal if the renal function is impaired or completely absent, such as end stage renal disease of a human being.

The blood from a patient is taken out into an extracorporeal circuit 2 including a filter or dialyser 1, including a semipermeable membrane 3. The blood passes along one side of the membrane. At the other side of the membrane, a dialysis fluid is circulated by the dialysis machine 4.

The dialysis fluid is usually prepared by the machine from one or several concentrates and water to form a dialysis fluid having the desired properties. Thus, the machine disclosed in Fig. 1 comprises a water inlet 5, two concentrate inlets 6 and 7, and two concentrate metering pumps 8 and 9. A first main pump 10 propels the fresh dialysis fluid to the dialysis side of the dialyser into contact with the membrane.

A second main pump 11 passes the effluent fluid, dialysate, from the dialyser, namely the inlet dialysis fluid and any ultrafiltrate removed from the blood via the filter, further on to an outlet 12 and to the drain.

A by-pass line 13 is arranged between the first pump 10 and the second pump 11. Several valves, 14, 15, and 16, are arranged for controlling the flow of dialysis fluid. The valves and the pumps are controlled by a computer 17 as schematically shown by several lines in Fig. 1. Of course, the dialysis machine is provided with several other means as is conventional. These other means are not disclosed, since they are conventional.

The first main pump 10 is driven with a speed so that the dialysis fluid delivered to the dialyser is substantially constant, e.g. 500 ml/min. The second main pump 11 is driven with a slightly higher speed so that the effluent fluid, called the dialysate, has a flow rate of e.g. 515 ml/min. This operation generates a low pressure at the dialysate side of the dialyser, which is suitable for removing 15 ml/min of ultrafiltrate fluid from the blood, i.e. plasma water. During a treatment of 4 hours, such ultrafiltration results in a fluid removal from the patient of 3,6 litres. Of course, the dialysis machine is operated so that the treatment prescribed to the patient is fulfilled.

In the effluent line from the dialysis machine is placed a urea monitor 18, which measures the urea concentration c_d in the effluent dialysate. The monitor can be positioned inside the dialysis machine or completely outside the dialysis machine. The urea monitor may be of the type disclosed in WO 96/04401.

The urea monitor is shown connected to the computer 17 of the dialysis machine. However, the monitor may have a computer of its own.

The urea monitor or the dialysis machine also includes means for measuring the flow rate of the effluent dialysate, Q_d. The computer 17 is arranged to provide concentration values c_d as well as values of the total mass of urea U removed during the treatment as the integral of $Q_d \cdot c_d$. The concentration values are taken continuously so that a concentration curve c_d is obtained from the urea monitor as well as a mass curve U.

Fig. 2 discloses a similar dialysis machine as shown in Fig. 1. The main difference is that the urea monitor 19 is placed between the dialyser 1 and the second main pump 11 and before the outlet of the bypass line.

Fig. 3 discloses a similar dialysis machine as Fig. 1, but adapted for hemofiltration or hemodiafiltration. The only difference is that there is included an infusion line 20 including an infusion pump 21. The infusion line 20 starts from the outlet of the first main pump 10 and ends at the blood inlet side of the dialyser, for providing an infusion fluid to the blood before the dialyser, called predilution. The urea monitor

22 is arranged in the effluent dialysate line after the second pump 11.

Fig. 4 discloses a similar dialysis machine as Fig. 2, but adapted for hemofiltration or hemodiafiltration and providing an infusion fluid to the blood after the dialyser, called postdilution. The urea monitor 23 is placed before the second main pump 11 and before the outlet of the bypass line.

Finally, Fig. 5 discloses a typical urea concentration curve c_d obtained from the urea monitor. As appears from the figure, the curve is very irregular and includes several dips. These dips reflect when the dialysis machine is connected for selfcalibration, in which valve 16 is opened and valves 14 and 15 are closed.

For the operation of the invention according to Swedish Patent Application No. 9702074-7, please refer to that application, which is included herein by reference. The result is that the urea monitor provides a removed urea concentration curve c_d as disclosed in Fig. 5. The initial values, for example values obtained from 5 minutes to 20 minutes, are used for extrapolating an initial urea concentration c_{d0} at the start of the dialysis treatment.

The start of the dialysis treatment is defined as the time when the urea concentration is steadily above a predetermined low concentration value. The actual determination of concentration values is initiated five minutes after determining such a steady condition in order to be sure that the treatment is going on and will not be discontinued.

In order to obtain a measurement of the effective dialyses of the dialyser, a disturbance is induced in the fresh dialysate by operating the pumps 8 and 9 controlled by the computer 17. The disturbance is generated when the dialysis treatment is in a steady state and may be a change in the ionic content of the dialysis fluid. Such a disturbance may be generated by operating both pumps 8 and 9 and increase the speed of these pumps by for example 10% during 60 seconds.

The resultant disturbance is measured after the dialyser, for example by a conductivity meter, and the measurement result is processed for example as described in

European application No
EP 658, 352 to obtain the effective dialysance K_e. The measurement is performed as soon as possible and preferably after the initial 20 minutes and without changing any of the parameters influencing on the dialysance of the dialyser, such as like blood flow rate and dialysate flow rate. European application No EP 658, 352 is incorporated herein in the present application by reference thereof.

If the disturbance is a step change in the conductivity, produced by pumps 8, and 9, the dialysance of the dialyser can be determined according to the following equation (see European application No EP 547, 025, the contents of which are also incorporated herein is included in the present application by reference thereof):

$$D_e = Q_d \, [1 - (c_{dout2} - c_{dout1}) / (c_{din2} - c_{din1})]$$

where

D_e = effective dialysance of the dialyser

Q_d = effluent dialysate flow

c_{dout1} and c_{dout2} = concentration in the effluent dialysate

c_{din1} and c_{din2} = concentration in the introduced dialysis fluid

The concentrations may be sodium concentrations or conductivity of the dialysate.

Indexes 1 and 2 indicate times before and after the step change. The introduced concentration can be measured before the dialyser or can be determined by the set values of the concentration pumps.

The value of the effective dialysance is used for determining the initial urea concentration in the blood at the start of the treatment, according to the formula:

$$c_{pw0} = Q_d \times c_{d0} / K_e$$

The plasma urea concentration can then be corrected for protein content in the blood. This correction is fairly constant for the normal range of protein concentrations, which allows the use of the same correction factor for all patients, although the best accuracy is achieved if the true protein content is used.

It is noted that the urea monitor includes a conductivity meter, which may be used for measuring the conductivity after the dialyser, so that there need not be any

separate conductivity meter after the dialyser for the measurement according to the present invention.

Instead of measuring the conductivity before the dialyser, the set values of the disturbance can be used.

The disturbance may be induced in different manners.

One approach is to use a small dose of urea, which is introduced in the fresh dialysis fluid just before the entrance into the dialyser as disclosed in Fig. 2. A pump 24 is connected to the inlet of the dialyser downstream of valve 14. The pump is also connected to a small bag 25 containing a predetermined quantity of urea dissolved in water or dialysis fluid (or an isotonic solution) and having a predetermined concentration.

The disturbance induced by this introduction of [the] a known amount of urea in the dialysis circuit is measured by the urea monitor downstream of the dialyser, and the result is evaluated by the computer 17. By integrating the measured urea concentration due to the disturbance, the mass of urea reaching the urea monitor can be calculated by multiplication with the flow rate Q_d. The difference from the amount introduced, which is known, must have passed through the membrane of the dialyser into the blood of the patient. Thus, the effective dialysance D_e or the effective clearance K_e for urea of the dialyser can be calculated, according to the following formula:

$$D_e = Q_d \times (1 - S_{out}/S_{in})$$

where:

D_e = effective dialysance of the dialyser

Q_d = dialysate flow emitted from the dialyser

S_{out} = integral of (cd(t) - cd0) during the disturbance in the flow emitted from the dialyser

S_{in} = integral of (cd(t) - cd0) during the disturbance in the flow entered into the dialyser

The best accuracy is obtained if the dialysate flow Q_d is constant, i.e. that the flow rate is compensated for the fluid added to the inlet of the dialyser as indicated more in detail[s] below.

Of course, the bag 25 may include sodium ions instead of urea and the conductivity meter of the urea monitor may be used for measuring the increased conductivity due to the introduction of extra sodium ions. It is known that the clearance for sodium ions is approximately equal to the clearance of urea. Other types of ions or substances can also be used as well as decreases instead of increases of the concentration or conductivity of the fresh dialysis solution.

If pure water is added, i.e. water without any ions or other substances, the integral given above will be negative, and the surface will have a relationship with the amount of added water.

It is noted that the integral S_{in} times the dialysis fluid flow equals the amount of material added to the solution. Thus, if urea is added, S_{in} need not be measured but can be calculated from the known amount of urea and the dialysis fluid flow. ~~Possibly, a~~ A correction for dilution may also be ~~is~~ required.

The same applies if sodium is used, whereby $S_{in} \times Q_{din}$ equals the addition of material in excess of the normal amount, which is normally ~~is~~ known in advance.

It is also apparent that the material can be added in any way that enables the measurement at the outlet side of the dialyser, i.e. the disturbance need not be rectangular, but can have any shape. Thus, the introduction flow rate of the material in the dialysate flow is of no importance as soon as it is of such a flow rate that the resultant disturbance is not too small to be measured and not to large to be outside the measuring capability of the measurement instrument at the outlet side of the dialyser. Of course, the disturbance must also be compatible with the body.

The added material can be dissolved in water, whereby the dilution effect should be considered when introducing the material in the circuit. Another approach would be to dissolve the material in normal dialysis fluid, for example to dissolve a known amount of urea in a known amount of dialysis fluid. This dissolution can be performed in advance, so that the material is delivered in bag 25 to be connected to the dialysis circuit. Alternatively, the material can be delivered in powder form, for

example a known amount of urea in powder form in a bag 25. The bag is connected to the dialysis machine, and the pump 24 is operated to introduce a known amount of dialysis fluid in the bag to dissolve the amount of material. After dissolution, the pump 24 is reversed and the material in the bag is introduced into the circuit.

The main pump 16 can be operated so that the total amount of fluid entering the dialyser is constant, i.e. the flow rate of pump 16 and pump 24 is constant. For example, if pump 24 is operated at a speed of 50 ml/min, pump 16 is reduced to 450 ml/min during the introduction period and returned to 500 ml/min after the introduction of the substance.

Alternatively, the disturbance may be introduced at the other side of the membrane as suggested in Fig. 2 by pump 26 and bag 27. In the same way as with pump 24 and bag 25, an introduction of urea of a known concentration and/or amount will result in an increase of the urea concentration in the dialysate reaching the urea monitor. This disturbance can be integrated and processed for obtaining the clearance of the dialyser.

The added material can be fresh dialysis fluid obtained from the dialysis machine, but of a higher (or lower) ionic strength or osmolarity, whereby the conductivity is measured. Alternatively, fresh dialysis fluid can be added, which comprises no urea, and the resulting diluting effect on urea in blood can be determined on the dialysate side by the urea monitor.

The added material, such as urea, can be diluted in water or dialysis fluid as indicated above. Moreover, the material can be delivered in powder form in a bag 27 and dissolved in blood by reversing pump 26 and introducing blood in the bag for dissolution of the material and then operating the pump 26 in the normal direction for introducing the material in the circuit.

The time of the measurement may be shortened by using the exponential behaviour of the disturbance for calculating the result as stated in European patent no. EP 658,352.

When using the integral method, the time may be shortened in the same way by estimating the error when the measurement is terminated in advance.

Hereinabove, the invention has been described in details by means of several embodiments of the invention. The different features in the different embodiments can be combined in further different ways, which combinations are intended to be within the scope of the present invention. The invention is only limited by the appended patent claims.

→ [INSERT C) ← attached

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533 Rec'd PCT/PTO 09 JUN 2000

INSERT A

In accordance with the present invention, these and other objects are now accomplished by the invention of a method of calculating the concentration of a predetermined substance in the blood of a mammal comprising passing the blood through one side of a semipermeable membrane in a dialyser and passing a dialysis fluid on the other side of the semipermeable membrane in the dialyser to provide a dialysate, measuring the concentration of the predetermined substance in the dialysate, introducing a disturbance in the dialyser, calculating the effective dialysance of the dialyser based on the disturbance, and calculating the concentration of the predetermined substance in the blood based upon the effective dialysance. In a preferred embodiment, the method includes determining the flow rate of the dialysate, and the calculating of the concentration of the predetermined substance in the blood comprises multiplying the measured concentration of the predetermined substance in the dialysate by the flow rate of the dialysate to provide a product and dividing the product by the effective dialysance. In accordance with a preferred embodiment, the measuring of the concentration of the predetermined substance in the dialysate is utilized to obtain a curve of the concentration over time, and the method includes calculating the initial mass of the predetermined substance in the blood, calculating the initial concentration of the predetermined substance in the blood, and calculating the distribution volume of the predetermined substance in the body by dividing the initial mass by the initial concentration of the predetermined substance in the blood.

In accordance with one embodiment of the method of the present invention, the introducing of the disturbance in the dialyser comprises changing the concentration of a second predetermined substance in the dialysis fluid, and the method includes measuring the

INSERT A

change in the concentration of the second predetermined substance in the dialysate.

In accordance with another embodiment of the method of the present invention, the method includes determining the flow rate of the dialysate, and the introducing of the disturbance in the dialyser comprises adding a predetermined amount of a second predetermined substance into the dialysis fluid, measuring the concentration of the predetermined substance in the dialysate, determining the amount of the second predetermined substance in the dialysate by multiplying the concentration of the second predetermined substance in the dialysate with the flow rate of the dialysate to obtain a product and integrating the product over time, and the calculating of the effective dialysance comprises multiplying the flow rate of the dialysate with a fraction comprising 1 minus the amount of the second predetermined substance in the dialysate over the amount of the second predetermined substance in the dialysis fluid.

In accordance with another embodiment of the method of the present invention, the second predetermined substance comprises sodium ions, a conductivity altering substance, or urea. In a preferred embodiment, the second predetermined substance comprises urea.

In accordance with the present invention, apparatus has also been provided for calculating the concentration of a predetermined substance in the blood of a mammal comprising a dialyser including a semipermeable membrane, means for passing the blood over one side of the semipermeable membrane in the dialyser, means for passing a dialysis fluid over the other side of the semipermeable membrane in the dialyser to produce a dialysate, concentration measuring means for measuring the concentration of the predetermined substance in the dialysate, disturbance means for introducing a disturbance in the dialyser, calculating means for

INSERT A

calculating the effective dialysance of the dialyser based on the disturbance, and concentration calculating means for calculating the concentration of the predetermined substance in the blood based on the effective dialysance. In a preferred embodiment, the apparatus includes flow rate means for obtaining the flow rate of the dialysate, the concentration calculating means comprising means for multiplying the concentration of the predetermined substance in the dialysate by the flow rate of the dialysate to provide a product, and dividing the product by the effective dialysance of the dialyser. Preferably, the concentration measuring means comprises means for measuring the concentration of the predetermined substance in the dialysate to obtain a concentration curve, and the apparatus includes mass calculating means for calculating the initial mass of the predetermined substance in the mammal, initial concentration calculating means for measuring the initial concentration of the predetermined substance in the mammal, and distribution volume calculating means for measuring the initial distribution volume of the predetermined substance in the mammal.

In accordance with one embodiment of the apparatus of the present invention, the disturbance means comprises means for changing the concentration of at least a predetermined substance in the dialysis fluid, and the apparatus includes measuring means for measuring the change in the concentration of the second predetermined substance in the dialysate.

In accordance with another embodiment of the apparatus of the present invention, the apparatus includes flow rate means for measuring the flow rate of the dialysate, and the disturbance means comprises means for introducing a predetermined amount of a second predetermined substance into the dialysis fluid, the concentration measuring means comprises means for measuring the concentration of the second predetermined

INSERT A

substance in the dialysate, and the apparatus includes an amount determining means for determining the amount of the second predetermined substance in the dialysate by multiplying the concentration of the second predetermined substance in the dialysate with the flow rate of the dialysate to provide a product and integrating the product over time, and the calculating means comprises means for multiplying the flow rate of the dialysate by a fraction comprising 1 minus the amount of the second predetermined substance in the dialysate over the concentration of the second predetermined substance in the dialysis fluid.

In accordance with a preferred embodiment of the apparatus of the present invention, the second predetermined substance comprises sodium ions, a conductivity altering substance, and/or urea. Preferably, the second predetermined substance comprises urea.

INSERT B

The present invention may be more fully understood with reference to the following detailed description, which, in turn, refers to the drawings in which:

INSERT C

Although the invention herein has been described with reference to particular embodiments, it is to be understood that these embodiments are merely illustrative of the principles and applications of the present invention. It is therefore to be understood that numerous modifications may be made to the illustrative embodiments and that other arrangements may be devised without departing from the spirit and scope of the present invention as defined by the appended claims.